NASA TECHNICAL TRANSLATION NASA TT F-14,994

ON THE ACCURACY OF AERODYNAMIC PARAMETERS FOR SIMULATION

B. Haftmann

(NASA-TT-F-14994) ON THE ACCURACY OF AERODYNAMIC PARAMETERS FOR SIMULATION (Scientific Translation Service) 18 p HC $3.00 CSCL 14B G3/11

N73-27178

Unclas 09232

Translation of "Uber die Genauigkeit der aerodynamischen Beiwerte für die Simulation," DGLR Report on the 3rd Meeting of the DGLR-Symp., Flight Testing Technol., Oct. 1972, pp. 53-66 (N73-19004 10-02)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, D. C. 20546 JULY 1973

1898

ON THE ACCURACY OF AERODYNAMIC PARAMETERS FOR SIMULATION

B. Haftmann

Introduction

The accuracy of the aerodynamic parameters is largely determined by the type and cost of the development process on which they are based.

If we start with the usual standard, then the process can usually be divided into three successive developmental stages. The first stage is the theoretical calculation of the parameters. This is done with the objective of finding a primary project definition from a given problem statement, or of providing the theoretical demonstration of the objectives to be met for a given project.

On this basis, then, there follow wind tunnel tests which serve to refine the project, to demonstrate or correct the values found theoretically, and to optimize influences which cannot be included in the theory.

The final stage of development is the recalculation of the wind tunnel results to the full-scale design conditions. This recalculation is not necessary in every case. It is done only if the flow characteristics of the large scale design and the model test do not agree, and if they affect the parameters. This applies primarily for the "classical" characteristic numbers,

* Numbers in the margin indicate pagination in the original foreign text.

the Reynolds number and the Mach number, which can be of decisive significance in evaluating the friction and compressibility effects.

As simulation appears reasonable only if the project has reached a certain stage of maturity, it is sufficient to investigate the most important error sources in the wind tunnel results and their recalculation.

/ 54

1. Error Sources in the Wind Tunnel Measurement

1.1 Types of mounting

Based on the physical flow characteristics, it has proved practical to divide the wind tunnel studies into a low velocity and a high velocity range. The low velocity test covers all the configurations flown in the incompressible flow, that is, up to $M = 0.3$. The high velocity test is concerned with the flight properties in the compressible flow region.

As the wind tunnel techniques must always be matched to the particular problem, the tests are usually done in different tunnels and on different models. This raises the problem of making the results agree at their boundaries by the most accurate possible correction of the outside effects which depend on the tunnel and the technique.

The usual configuration-independent tunnel corrections (jet tilt, stagnation pressure, angle of incidence, Mach number) are part of the fixed component of the institute evaluation. They are the result of many test series can can be taken as quite accurate.

But there are other corrections which must be applied, arising from the interference effects of the model mounting.

These corrections depend on the project. In part, they can be of the order of magnitude of the true value, so that they represent the inherent error sources for a measurement. The most common mounting types, wire and post mounting, are shown in Figure 1. Aside from special measurements which require air supply or suction tubes to the model, the wire mounting is preferred in the low velocity range.

The reason for this is the lack of interference and the stiffness of this type of mounting. As a rule, no correction is needed for the lift and moments. The wires have a bad effect on the drag measurements. As the entire wire drag is included in the measurement, and this can be of the magnitude of the true aircraft drag, a correction becomes very questionable, and the drag measurement becomes inaccurate. /55

In the high velocity region, the lack of interference disappears because of the reflection of compression shocks on the model and tunnel wall. For that reason, the post mounting is used. Its disadvantage, to be sure, is a strong falsification of the flow around the tail, affecting primarily the moment balance.

The order of magnitude of the correction required depends on the relation of the post diameter to the tail section span and attitude. In the case of the VAK [1] this corresponds to a change in trim angle by some two degrees.

1.2 Similarity characteristics

The "classical similarity characteristics of wind tunnel tests are the Reynolds number and the Mach number. But with the

(1) Translator's note: expansion unknown.

development of VSTOL aircraft, one characteristic quantity is steadily gaining importance. It is intended to provide a simulation of the engine jets in the model experiments. It states that the perturbation velocities induced by the jet and the directions of the flow particles are determined, for geometrically similar configurations, by the ratio of the jet outlet stagnation pressure to the incident flow stagnation pressure. Figures 2 and 3 show one investigation on this theme, with two typical VAK configurations as examples.

We find that the change of the incident flow stagnation pressure has an effect, with a distinctly detectable tendency, at constant similarity characteristic. This fact makes it quite difficult to transfer the wind tunnel results to the full scale design, and we must count on errors up to $\pm$ 25% of the measured jet influence. Figure 4 shows a comparison of measurements at / 56
different Reynolds numbers.

Investigation of the influence of the Reynolds number is of importance, then, because as a rule the flight Reynolds number is always considerably above the attainable model Reynolds number. We find that as the characteristic number increases

- the maximum lift becomes greater
- the form drag becomes less (at $c_A \to 0$) and
- the wing-fuselage moment becomes more nose-heavy with flaps extended.

Aside from the form drag change, the Reynolds number influence is primarily importante in flow ranges which are exposed to large aerodynamic stresses (large incidence and sideslip angles, large flap and elevator deflections). Because of complex flow processes in these regions, correction of the wind tunnel results is possible only with the use of semiempirical methods. Later, we shall consider the omissions required in that case.

1.3 Measuring equipment

The usual 6-component measurements are made using scales. Their accuracy of $\pm$ 20 p is entirely sufficient.

For special measurements, typical ones being hinge moment measurements on flaps and elevators, it is necessary to develop special strain gauge scales. They have to match the given location conditions, and must be designed for relatively large forces (high velocity range), so that their accuracy suffers. Figure 5 shows the result of one measurement on the rudder of the VFW-614.

The measurement was interrupted for about 14 days, and the model was taken out of the tunnel. The following measure- / 57
ment on the same model could not be made to agree at the boundaries. Figure 6 shows a comparison between the wind tunnel measurement and a rolling test on the full scale design. At the same time, we can determine what fluctuations occur from friction and dynamic effects in the full scale design. Hinge moment measurements on the model, then, must be considered as more than guide values which are to be provided with fluctuation bandwidths in the control design and in the simulation.

2. Correction of the Wind Tunnel Results to the Full Scale Conditions

The correction extends to all those areas of the aerodynamic parameters which are only partially simulated in model measurements (such as the engine jet and intake flow simultaneously) or in which the differing flow characteristic numbers play a role. Comparison between measured and calculated maximum lifts and form drags versus the Reynolds number may serve as an example (Figure 7).

In neither case do the absolute values agree. The reasons are of manifold nature. They extend from the calculating method to the measurements. In both cases, the effects of these quantities:

- degree of flow turbulence
- construction inaccuracies
- surface roughness
- interferences between different parts

could be determined only approximately (interferences) or not at all.

Aside from these, the tendency versus the Reynolds number is confirmed well, so that extrapolation of the measurements to the flight range can be undertaken with satisfactory accuracy. This does not include the roughness, degree of turbulence, and construction inaccuracies which differ between the model and the large-scale design. / 58

3. Summary

It appears that the accuracy of the aerodynamic parameters cannot be judged in one lump. Rather, they are determined by influences of varying significance. For this reason, different error sizes arise for the various parameters.

A survey is presented in tabular form in Figure 8. The quantities determining the errors are arranged in approximate order of their effect. This assumes that the constructional inaccuracies and surface roughness meet the ordinary standard for high performance aircraft.

The data presented make no claim for completeness and generality. They are intended primarily to communicate a feeling for the order of magnitude of the errors and the factors which determine them.

Figure 1. Wind tunnel mounting types, corrections, characteristics

Figure 2. Transition; effect of the incident flow velocity

Figure 3. End of transition; effect of the incident flow velocity

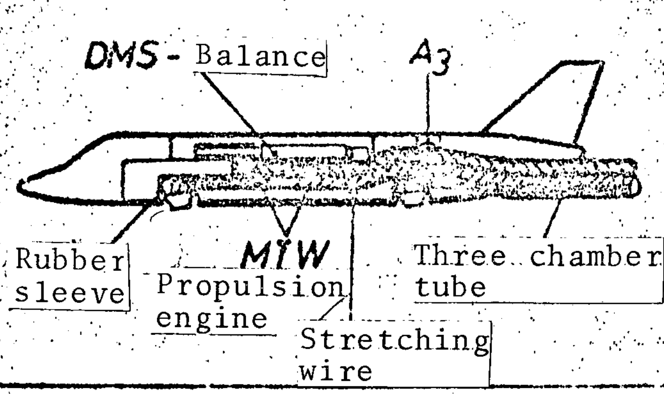
Figure 4. Moments, drags; effect of the Reynolds number

Figure 5. Hinge moment; rudder

Figure 6. Hinge moment; elevator

Figure 7. Effect of the Reynolds number

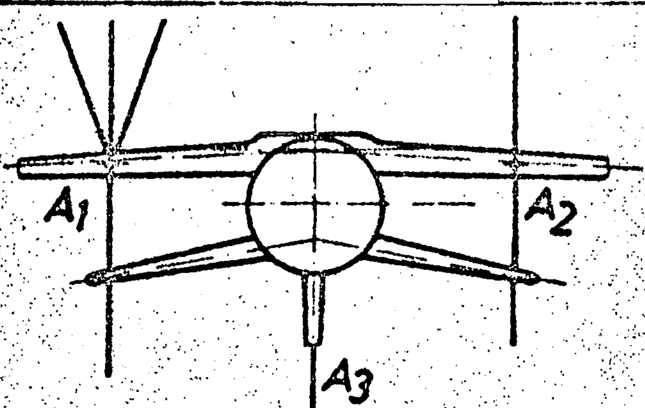
Figure 8. Quantities affecting the judgment of the accuracy of aerodynamic factors.



Type:
Sting suspension

Task:
Jet simulation

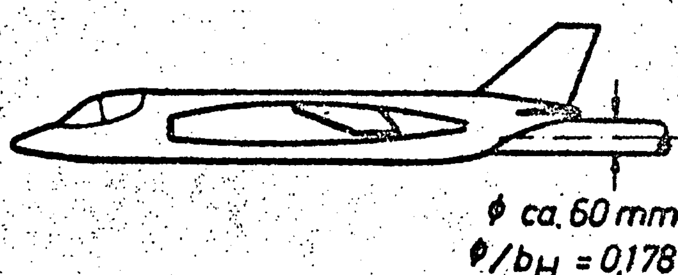
Problem:
Correction of moments,
Similarity coefficient



Type:
Wire suspension

Task:
Low velocity measurement

Problem:
Correction of drag,
Similarity coefficient



Type:
Sting support

Task:
High velocity measurement

Problem:
Correction of moments

Similarity coefficients

$$Re = \frac{V_\infty \cdot l}{\nu}$$

$$M_\infty = \frac{V_\infty}{a}$$

$$\phi = \frac{q_A}{q_\infty}$$

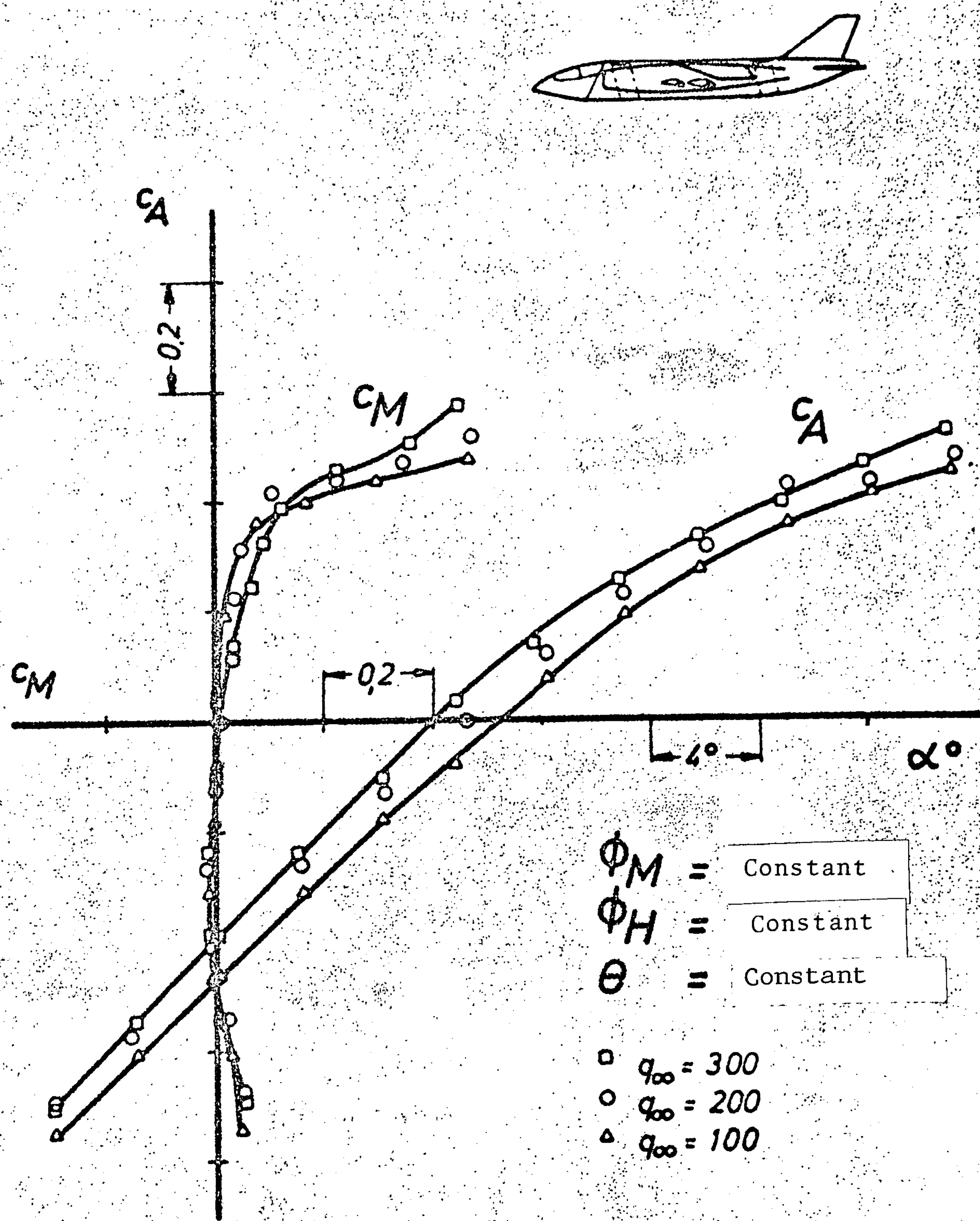
Corrections

$$\Delta c_{W_D} = c_{W_0}$$

$$\Delta c_{M_{ST}} = -0{,}05 \div -0{,}062 \mathrel{\hat{=}} \Delta\varepsilon \approx 2^\circ \ (VAK)$$

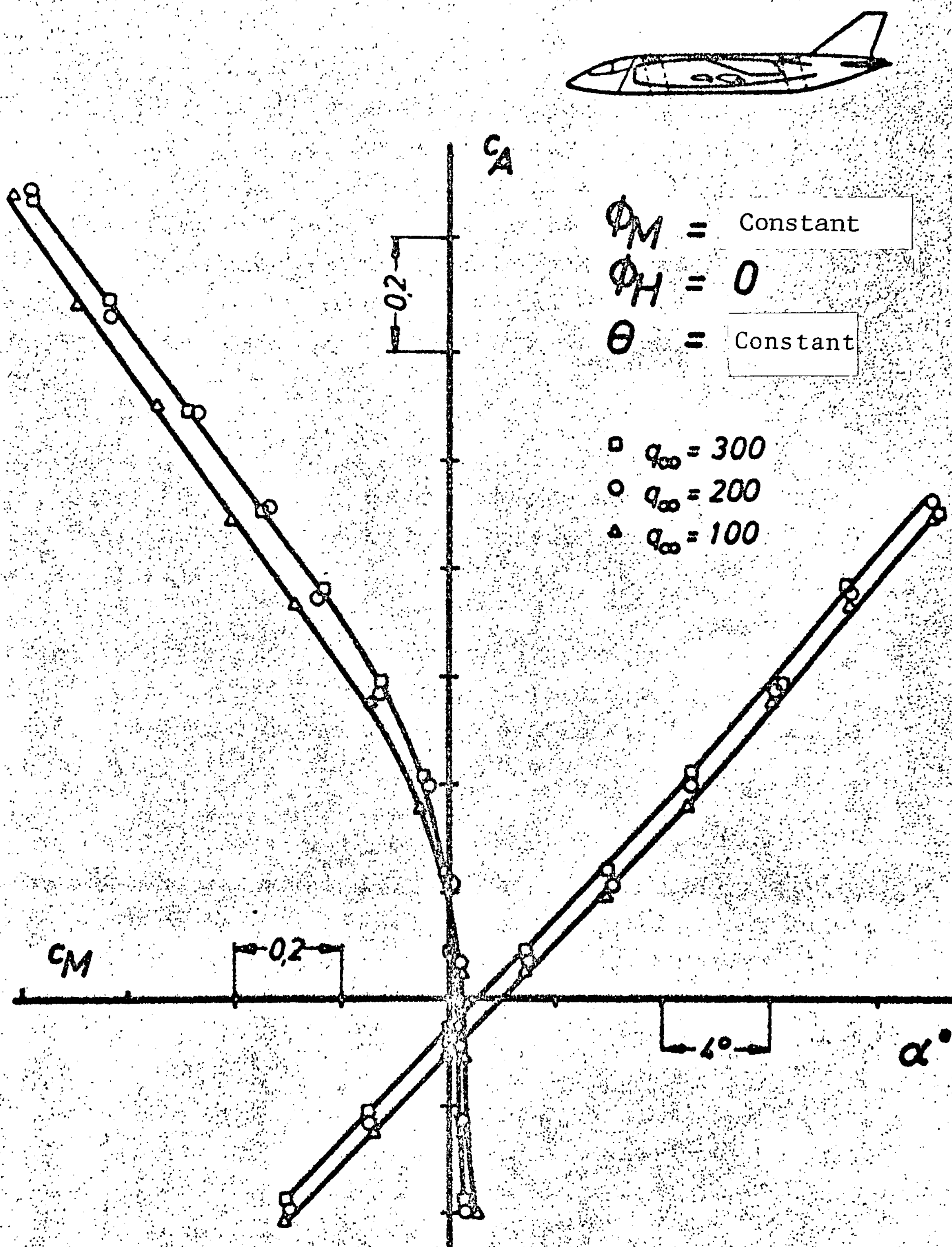
$$\Delta c_{M_{ST}} = -0{,}023 \div -0{,}025 \mathrel{\hat{=}} \Delta\varepsilon \approx 0{,}5^\circ \ (614)$$

Figure 1



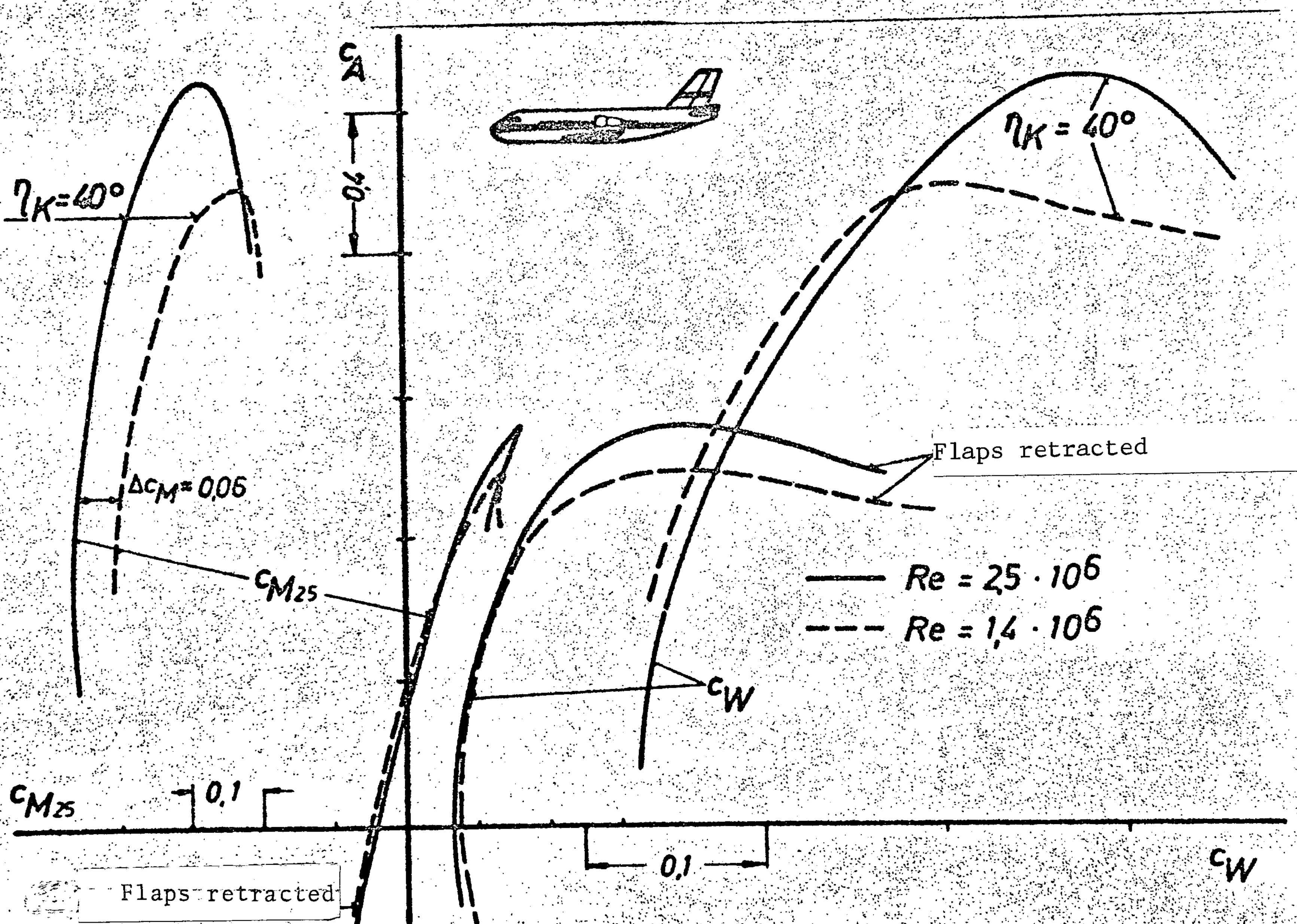
c_A
0,2
c_M
c_A
c_M
0,2
4°
α°
ϕ_M = Constant
ϕ_H = Constant
θ = Constant
q_∞ = 300
q_∞ = 200
q_∞ = 100

Figure 2



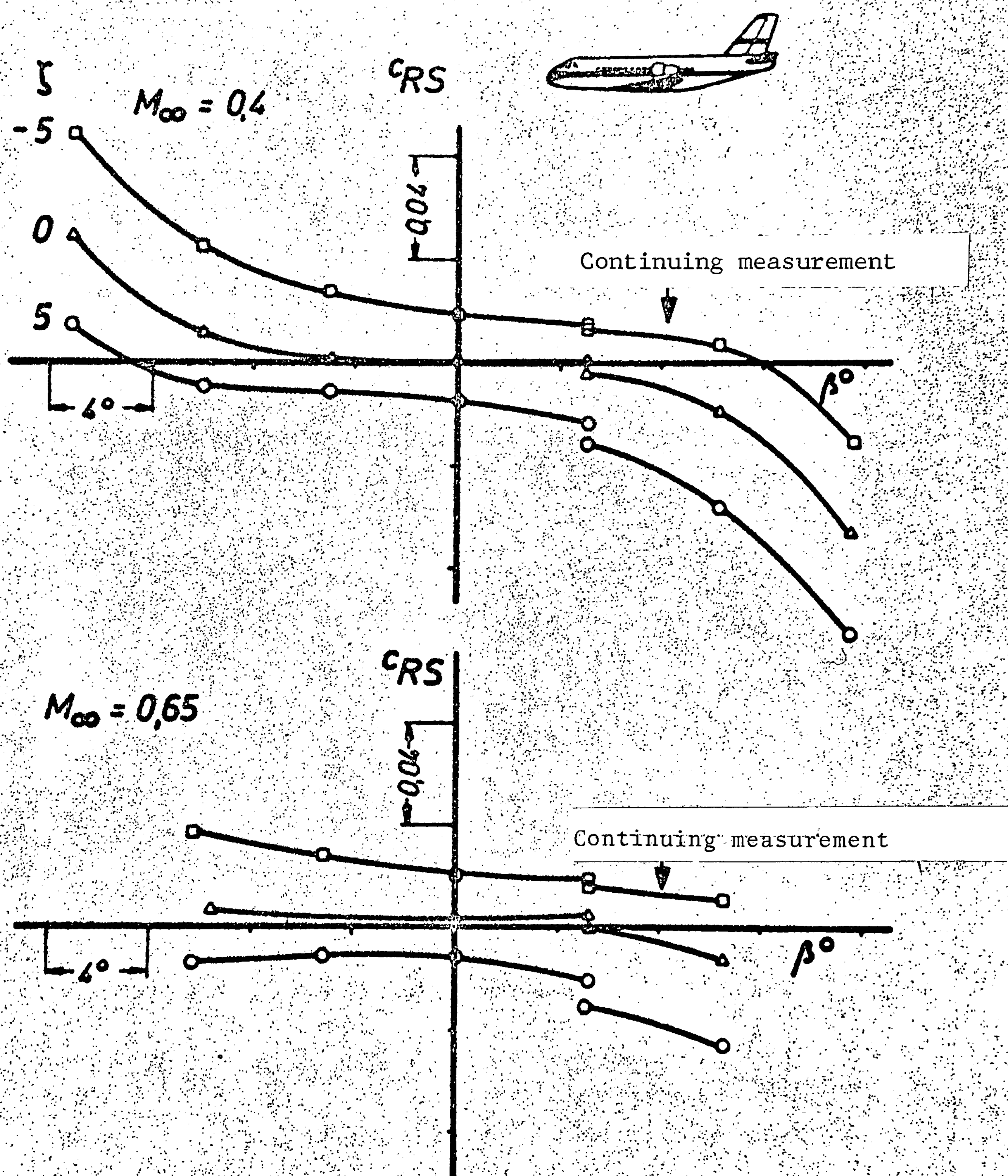
c_A
0,2
ϕ_M = Constant
ϕ_H = 0
θ = Constant
q_∞ = 300
q_∞ = 200
q_∞ = 100
c_M
0,2
4°
$\alpha°$

Figure 3



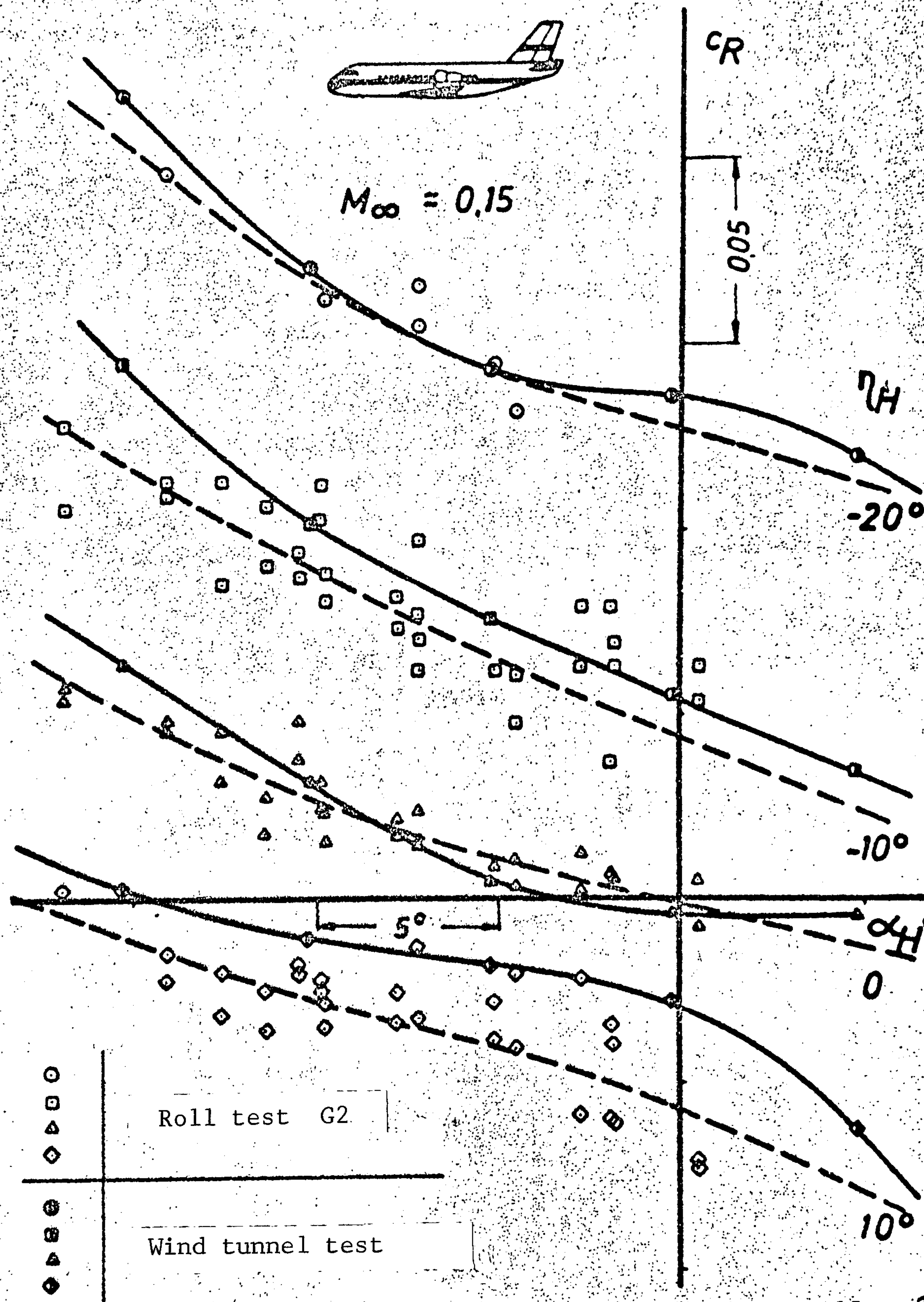
c_A
1,0
η_K=40°
η_K = 40°
Flaps retracted
Δc_M=0,06
c_M25
Re = 2,5 · 10^6
Re = 1,4 · 10^6
c_W
c_M25
0,1
0,1
c_W
Flaps retracted

Figure 4



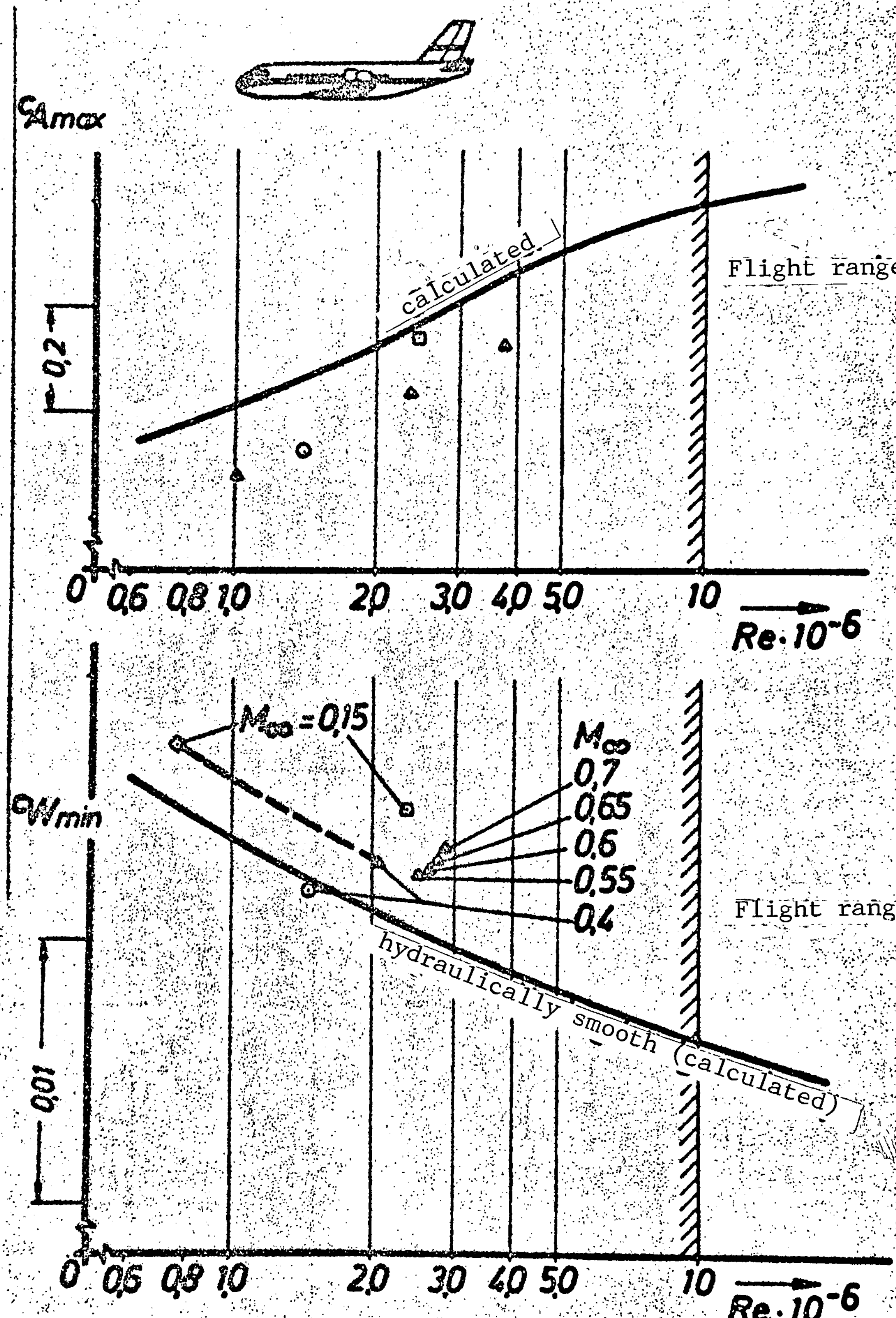
ζ
$M_\infty = 0{,}4$
c_{RS}
-5
0
5
0,04
Continuing measurement
4°
$\beta°$
c_{RS}
$M_\infty = 0{,}65$
0,04
Continuing measurement
4°
$\beta°$

Figure 5



c_R
$M_\infty = 0{,}15$
0,05
η_H
-20°
-10°
0
10°
5°
α_H°
Roll test G2
Wind tunnel test

Figure 6



c_{Amax}
calculated
Flight range
0,2
0
0,6
0,8
1,0
2,0
3,0
4,0
5,0
10
$Re \cdot 10^{-6}$
$M_\infty = 0,15$
M_∞
0,7
0,65
0,6
0,55
0,4
c_{Wmin}
Flight range
hydraulically smooth (calculated)
0,01
0
0,6
0,8
1,0
2,0
3,0
4,0
5,0
10
$Re \cdot 10^{-6}$

Figure 7

Factors affecting judgement of the accuracy of aerodynamic quantities				
Aircraft	Parameter	Secondary influences	Primary influences	Total accuracy, approximately
Wing with large aspect ratio	Maximum lift	Wind tunnel scales + 20 p Stagnation pressure + 0.3% Model mounting	Reynolds number Roughness Construction inaccuracies	± 5%
	Moment	Angular setting accuracy= ± 0.2°	Reynolds number Construction inaccuracies Wind tunnel corrections	± 6% (Landing ± 3% (High-speed flight
	Drag	./.	Wind tunnel corrections Reynolds number Roughness	± 3%
	Hinge moment	Wind tunnel technique	Measuring equipment ± 5% Reynolds number Construction inaccuracy Positioning accuracy	± 10%
Wing with small aspect ratio	Maximum lift	Reynolds number	./.	± 3%
	Moment	Reynolds number Angular setting accuracy = ± 0.2°	Wind tunnel corrections Construction inaccuracies	± 5%
	Drag	./.	Wind tunnel corrections Reynolds number Roughness Construction inaccuracies	± 3%
	Jet effect	Reynolds number	Jet characteristic Wind tunnel technique	± 25%

Figure 8

Translated for National Aeronautics and Space Administration
under contract No. NASw 2483, by SCITRAN, P. O. Box 5456,
Santa Barbara, California, 93108

STANDARD TITLE PAGE

1. Report No. NASA TT F-14,994	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle ON THE ACCURACY OF AERODYNAMIC PARAMETERS FOR SIMULATION		5. Report Date July 1973
		6. Performing Organization Code
7. Author(s) B. Haftmann		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASw-2483
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of: Uber die Genauigkeit der aerodynamischen Beiwerte für die Simulation

Source: DGLR Report on the 3rd Meeting of the DGLR-Symp. Flight Testing Technol., Oct. 1972, pp. 53-66, (N73-19004 10-02)

16. Abstract

The procedure for developing the aerodynamic parameters for use in flight simulator research projects is described. Emphasis is placed on wind tunnel measurements to determine aerodynamic coefficients. Sources of error in wind tunnel measurements are analyzed. Procedures for compensating for errors arising during wind tunnel tests are explained. Results of a typical investigation are presented as graphs.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	17	